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**Effects of forest harvesting on soil amorphous aluminosilicates (imogolite-type material) and implications for water quality**

*Stephanie Grand*, University of British Columbia*
*Dr. Leslie Lavkulich, University of British Columbia*
*Dr. Robert Hudson, Vancouver Forest Region*

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Forest harvesting is a major threat to environmental quality in the Puget Sound Georgia Basin area. One of the impacts of logging is increased aluminum levels in soil and water. The classic study of Likens et al. (1970) showed a ten-fold increase in stream aluminum concentration as a result of clear-cut logging with vegetation re-growth suppressed for two years by herbicides.

High levels of dissolved aluminum in streams have been shown to cause mortality in fish and aquatic invertebrates. Dissolved aluminum precipitates as aluminum hydroxide in fish gills and causes respiratory problems. Aluminum is also toxic to aquatic and terrestrial plants (Gensemer and Playle, 1999).

The mechanism by which aluminum is released into soil and water following harvesting is still unclear. Aluminum pools that may be mobilized by logging include (1) exchangeable aluminum, which could be displaced into solution following soil acidification, (2) organically-complexed aluminum, which could be released due to increased organic matter decomposition, and (3) poorly crystalline aluminosilicate minerals, which could be dissolved due to geochemical changes. This study focuses on the last hypothesis.

Poorly crystalline aluminosilicates are often referred to as imogolite-type material (ITM). They comprise (1) imogolite, a mineral of fixed composition with a structural formula $(OH)_3Al_2O_3Si\ OH$, and (2) allophane, a group name for non-crystalline clay minerals consisting of variable amounts of $O^{2-}$, $OH^-$, $Al^{3+}$, and $Si^{4+}$ (Sumner, 2000). Both minerals are only a few nanometers in size. ITM is a very common mineral in the B horizon of Podzols or Spodosols, two closely related soil types found in areas dominated by cool, humid to per-humid climates and under forest or heath vegetation in medium to coarse-textured material. In North America Podzols and Spodosols are extensively developed in mountainous areas of the West, around the Great Lakes region, eastern Canada, and the northeastern United States.

Because of its poorly crystalline nature, ITM is among the most reactive components of soil. It is readily solubilized following environmental disturbance to yield toxic Al species. This study investigates the role played by ITM in watershed response to forest harvesting.

The sampling area is located in the Roberts Creek Study Forest (Sunshine Coast), about 40 km North West of Vancouver, BC. The area is characterized by low elevation (ranging from 350 to 500 m above sea level), gentle slopes (average gradient of 15%), and a southwesterly aspect. It lies within the Pacific Range Drier Maritime variant of the Coastal Western Mountain Hemlock Zone (CWHdm). Douglas fir is the dominant vegetation specie. The climate is characterized by warm, relatively dry summers and moist, mild winters with little snowfall (D'Anjou, 2002).

Soils are ferric Podzols in the Canadian system of soil classification. The soil profile consists in from top to bottom: (1) organic layer LFH (3-15 cm in thickness), (2) eluvial horizon Ae (2-10 cm thickness), which contains less base cations, Al, and Fe than the parent material and is enriched in residual Si, (3) Bf horizon (25-35 cm thickness), enriched in poorly crystalline Al and Fe minerals, (4) BC horizon (20 to 40 cm thickness) showing mottling, a sign of alternating reduced and oxidized conditions, and (5) C horizon consisting in basal till with little sign of soil development.

We collected soil samples from undisturbed forested plots (control, essentially undisturbed for the past 140 years), and compared them to samples from plots that were clear-cut 1, 2, 3, 5, and 8 years ago. We sampled all soil horizons from H (humified part of the organic layer) to C. Samples were analyzed for ITM content using selective dissolution analysis and transmission electron microscopy. Other analysis conducted for site characterization include soil pH, texture, water-soluble (soil solution) Al and Si, exchangeable cations, chloride retention (an estimate of anion exchange capacity), organic matter and organic carbon content, plant-available nutrients (nitrate and phosphate), and microbial respiration.

Selective dissolution of the ITM material revealed that the atomic Al/Si ratio equals 2, suggesting the presence of imogolite or proto-imogolite. Transmission electron micrographs showed no sign of imogolite morphology (tubes or threads). For that reason ITM in Roberts Creek Forest is believed to consist in poorly ordered proto-imogolite. Differential X-rays diffraction will be conducted next summer to confirm this result.

Preliminary results indicate that ITM is present in all samples in the Bf to C horizon. There is no sign of ITM in the H and Ae horizons, where aluminum concentrations are kept too low for aluminosilicate neoformation by complexation with organics or eluviation (leaching to lower horizons).

Control sites (undisturbed forest) are very high in ITM, containing up to 40 g/kg of proto-imogolite in the B and C horizons. This value is among the highest reported in the literature for Podzols (Lundstrom et al., 2000b; Mossin et al., 2002). ITM content decreases significantly as time after harvesting increases, reaching a low of 5g/kg after 8 years. There is no sign of recovery of the ITM pool at 8 years following logging.

These results suggest that clear-cut logging may cause ITM dissolution. It is an encouraging finding that suggests ITM could in some cases be responsible for the occurrence of Al toxicity following forest harvesting. More extensive sampling is needed to confirm this result.

We are also conducting a wide variety of geochemical and biochemical analyses to characterize soil properties at all sampled plots. This should allow us to identify which changes in the soil system are directly responsible for ITM dissolution. The environmental significance of ITM dissolution is also investigated. Data on soil solution Al, exchangeable Al, and stream Al has been collected and is analyzed to determine whether ITM dissolution is linked to increased soluble Al in soil and water.

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